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EPA's Composite Model for Leachate Migration with Transformation Products (EPACMTP)

Parameters/Data Background Document

April 2003

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U.S. Environmental Protection Agency
Office of Solid Waste
Washington, DC 20460

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ACKNOWLEDGMENTS

A large number of individuals have been involved with the development of EPACMTP since its inception in the early 1990's. Dr. Zubair A. Saleem of the U.S. EPA, Office of Solid Waste (EPA/OSW) has coordinated and guided the development of EPACMTP throughout much of this period. Ms. Ann Johnson, Mr. David Cozzie, and Mr. Timothy Taylor provided review for the development of this background document. This report was prepared by the staffs of HydroGeoLogic, Inc. (HGL), and Resource Management Concepts, Inc. (RMC), under EPA Contract Number 68-W-01-004.

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LIST OF SYMBOLS AND ABBREVIATIONS

Symbol	Definition	Section
A_r	anisotropy ratio = K_x/K_z	5.3.6
A_w	area of a WMU (m^2)	2.3.1, 2.4.1, 2.5.1, 2.6.1
B	thickness of the saturated zone (m)	5.3.4.3, 6.6
C_d	metal concentration in the dissolved phase at equilibrium (mg/L)	3.3.3.2
C_s	metal concentration in the sorbed phase at equilibrium (mg/L)	3.3.3.2
C_L	leachate concentration (mg/L)	3.2.3
CV	coefficient of variation (%)	5.2.4
C_w	constituent concentration in the waste (mg/kg)	3.2.2
d_{BG}	depth below grade of WMU (m)	2.3.3, 2.4.6, 2.5.3
D_i	molecular diffusion coefficient in free water for species i (m^2/yr)	3.3.1.1
D_{LF}	landfill depth (m)	2.3.2
D_{lin}	liner thickness (m)	2.4.4
D_s	total sediment thickness (m)	2.4.3
D_u	total depth of the unsaturated zone (m)	5.2.1
D^{s*}	effective molecular diffusion coefficient for species of interest (m^2/y)	6.6
DWS	drinking water standard (mg/L)	3.3.1.2
E_a	Arrhenius activation energy (Kcal/mol)	3.3.2.2.3
F_h	volume fraction of the waste in the landfill at time of closure (m^3/m^3)	2.3.4
FeOx	iron hydroxide content (wt % Fe)	3.3.3.2.3
f_{oc}	fractional organic carbon content (dimensionless)	3.3.3.2.6
f_{oc}^s	fractional organic carbon content of the aquifer material (dimensionless)	5.3.11
g	gravitational acceleration (m/s^2)	5.3.4.4
$[H^+]$	hydrogen ion concentration (mol/L)	3.3.2.2.1
H_P	SI ponding depth (m)	2.4.2
I	annual infiltration rate through the source (m/y)	4.3.1, 4.3.2, 4.3.3, 4.3.4
ICLR	climate center index	4.2
ID	metal identification number (unitless)	3.3.3.2.1
IGWR	hydrogeologic environment index (unitless)	3.3.3.2.7,5.3.4.2
IGWT	ground-water type - carbonate/non-carbonate (unitless)	3.3.3.2.7
ISTYPE	soil type	5.2.2

LIST OF SYMBOLS AND ABBREVIATIONS (continued)

Symbol	Definition	Section
IWLOC	R_{rw} (Receptor well) origination method	6.5
I_R	effective recharge rate outside the strip source area (m/y) or recharge rate outside the source area (m/y)	4.4
J	symbol used to denote a for the acid-catalyzed reaction, b for the base-catalyzed reaction and n for the neutral reaction	3.3.2.2.3
K	hydraulic conductivity (m/yr)	5.3.4.4
k_1	nonlinear Freundlich parameter for the unsaturated zone (mg constituent/kg dry soil))	5.2.9
K_a^T	acid-catalyzed hydrolysis rate constant (1/(mol.yr))	3.3.2.2.1
K_a^{Tr}	acid-catalyzed hydrolysis rate constant at reference temperature (1/(mol.yr))	3.3.2.2.3
K_b^T	base-catalyzed hydrolysis rate constant (1/(mol.yr))	3.3.2.2.2
K_b^{Tr}	base-catalyzed hydrolysis rate constant at reference temperature (1/(mol.yr))	3.3.2.2.5
K_d	distribution (solid-aqueous phase) partition coefficient in the unsaturated zone (cm^3/g) (Freundlich Coefficient)	3.3.3, 5.2.8
K_d^s	solid-liquid distribution coefficient of the aquifer (cm^3/g)	5.3.12
K_J^T	hydrolysis rate constant for reaction process J, corrected for the subsurface temperature T (1/(mol.yr) for the acid- and base-catalyzed reactions; 1/yr for the neutral reaction)	3.3.2.2.3
K_J^{Tr}	hydrolysis rate constant for reaction process J, measured at the reference temperature T_r (1/(mol.yr) for the acid- and base-catalyzed reactions; 1/yr for the neutral reaction)	3.3.2.2.3
K_{lin}	saturated hydraulic conductivity of liner (m/y)	2.4.5
K_n^T	neutral hydrolysis rate constant at (1/yr)	3.3.2.2.1
K_n^{Tr}	neutral hydrolysis rate constant at reference temperature (1/yr)	3.3.2.2.3
k_d	soil-water partition coefficient (L/kg)	3.3.2.1
k_{oc}	constituent-specific organic carbon partition coefficient (cm^3/g)	3.3.2.1
k_{ow}	octanol-water partition coefficient (cm^3/g)	3.3.2.1
K_s	saturated hydraulic conductivity (cm/hr)	5.2.3
K_x	hydraulic conductivity in the *x* direction (m/y)	5.3.5
K_y	hydraulic conductivity in the horizontal transverse (y) direction (m/y)	5.3.6
ℓ	daughter species number	3.3.2.3.1
LOM	leachate organic acid concentration (mol/L)	3.3.3.2.4
LYCHK	constraint on well distance from plume centerline	6.5
LZCHK	constraint on depth of intake point below water table	6.6

LIST OF SYMBOLS AND ABBREVIATIONS (continued)

Symbol	Definition	Section
ℓ	daughter species number	3.3.2.3.1
LN	log normal distribution	5.2.2
M	number of immediate parent species	3.3.2.3.2
m	species number of immediate parent	3.3.2.3.3
MW_ℓ	molecular weight of species ℓ (g/mol.)	3.3.1.3
N	sample size	5.2.4
NO	Normal distribution	5.2.2
$[OH^-]$	hydroxyl ion concentration (mol/L)	3.3.2.2.2
%OM	percent organic matter (dimensionless)	3.3.3.2.5, 5.2.7
PWS	waste volume (m^3)	2.3.5
pH	ground-water pH (standard units)	3.3.3.2.2, 5.2.10, 5.2.13
Q_1^F	background ground-water flux (m^2/y)	6.6
Q_4^F	recharge flux downgradient of the source (m^2/y)	6.6
r	regional hydraulic gradient (m/m)	5.3.4.5
R_g	Universal Gas Constant (1.987E-3 Kcal/deg-mol)	3.3.2.2.3
R_ℓ	retardation factor for species l (dimensionless)	3.3.2.1
R_{rw}	radial distance between waste management unit and well (m)	6.2
R_∞	distance between the center of the source and the nearest downgradient boundary where the boundary location has no perceptible effects on the heads near the source (m)	2.4.8
R^s	retardation coefficient (dimensionless)	5.3.7
SB	log ratio distribution	5.2.2
SD	standard deviation	5.2.4
T_r	hydrolysis reference temperature (°C)	3.3.2.2.6
T	ground-water/subsurface temperature (°C)	3.3.2.2.3, 5.2.12, 5.3.9
t_d	exposure time interval of interest (yr)	6.8
t_p	leaching duration (yr)	2.3.6, 2.4.9, 2.5.2, 2.6.2
V_x	longitudinal ground-water (seepage) velocity (in the x-direction) (m/y)	5.3.5
X	sample mean	5.2.4
x	principal Cartesian coordinate along the regional flow direction (m)	6.4
x_{rw}	distance from the downgradient boundary of the WMU to the receptor well (m)	6.4

LIST OF SYMBOLS AND ABBREVIATIONS (continued)

Symbol	Definition	Section
x_t	average travel distance in the x direction (m)	5.3.8.1
x_w	length of the WMU in the x-direction (parallel to ground-water flow) (m)	6.6
y	principal Cartesian coordinate normal to the flow direction, or distance from the plume centerline (m)	6.5
y_D	source width along the y-axis (m)	6.5
y_{rw}	Cartesian coordinate of the receptor well in the y-direction (m)	6.5
z	principal Cartesian coordinate in the vertical direction (m)	6.6
z^*_{rw}	z-coordinate of the receptor well positive downward from the water table(m)	6.6
	GREEK SYMBOLS	
α	van Genuchten soil-specific shape parameter (1/cm)	5.2.2, 5.2.4.1
α_L	longitudinal dispersivity of the aquifer (m)	5.3.8.1, 6.6
α_{Lu}	longitudinal dispersivity in the unsaturated zone (m)	5.2.6
α_{Ref}	reference longitudinal dispersivity, as determined from the probabilistic distribution (m)	5.3.8.1
α_T	horizontal transverse dispersivity (m)	5.3.8.2, 6.5
α_V	vertical transverse dispersivity (m)	5.3.8.2, 6.6
β	van Genuchten soil-specific shape parameter (dimensionless)	5.2.2, 5.2.4.2
γ	van Genuchten soil-specific shape parameter (dimensionless) = 1 -1/β	5.2.4
η	species-specific nonlinear Freundlich exponent for the unsaturated zone	5.2.9
η^s	Freundlich exponent for the saturated zone (dimensionless)	5.3.13
θ	soil water content (dimensionless)	3.3.2.1
θ_r	residual soil water content (dimensionless)	5.2.4.3
θ_{rw}	angle measured counter-clockwise from the plume centerline (degrees)	6.3
θ_s	saturated soil water content (dimensionless)	5.2.4.4
λ	overall first-order hydrolysis transformation rate(1/y)	3.3.2.2
λ_1	hydrolysis constant for dissolved phase (1/y)	3.3.2.2.2
λ_2	hydrolysis constant for sorbed phase (1/y)	3.3.2.2.1
λ_b^s	biodegradation rate in the saturated zone (1/yr)	5.3.15
λ_c^s	chemical degradation rate in the saturated zone (1/yr)	5.3.14
λ_{bu}	transformation coefficient due to biological transformation (1/y)	5.2.11

LIST OF SYMBOLS AND ABBREVIATIONS (continued)

Symbol	Definition	Section
λ_{cu}	transformation coefficient due to chemical transformation (1/y)	5.2.10
μ	dynamic viscosity of water (N-s/m^2)	5.3.4.4
$\xi_{\ell m}$	stoichiometric fraction of parent m that degrades into daughter ℓ/speciation factor (dimensionless)	3.3.2.3.4
ρ	density of water (kg/m^3)	5.3.4.4
ρ_b	bulk density of the aquifer (g/cm^3)	3.3.2.1, 5.3.3
ρ_{bu}	soil bulk density of the unsaturated zone (g/cm^3)	5.2.5
ϕ	*porosity/water content in the unsaturated zone* (dimensionless)	3.3.2.2, 5.3.2
ϕ_e	effective porosity of the saturated zone (dimensionless)	6.6

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1.0 INTRODUCTION

This document provides background information on the parameters and data sources used in EPA's Composite Model for Leachate Migration with Transformation Products (EPACMTP). EPACMTP is a subsurface fate and transport model used by EPA's Office of Solid Waste in the RCRA program to establish regulatory levels for concentrations of constituents in wastes managed in land-based units. This document describes the EPACMTP input parameters, data sources and default parameter values and distributions that EPA has assembled for its use of EPACMTP as a ground-water assessment tool. EPA has also developed a complementary document, the *EPACMTP Technical Background Document* (U.S. EPA, 2003a), which presents the mathematical formulation, assumptions and solution methods underlying the EPACMTP. These two documents together are the primary reference documents for EPACMTP, and are intended to be used together.

The remainder of this section describes how this background document is organized. The parameters and data are documented in six main categories, as follows:

- Section 2 describes the Waste Management Unit (Source) Parameters;
- Section 3 describes the Waste and Constituent Parameters;
- Section 4 describes the Infiltration and Recharge Parameters;
- Section 5 describes the Subsurface Parameters;
- Section 6 describes the Ground-water Well Location Parameters; and
- Section 7 provides a list of References

Several appendices provide complete listings of data distributions for a number of the EPACMTP input parameters.

To facilitate the cross-referencing of information between this document and the *EPACMTP Technical Background Document* (U.S. EPA, 2003a), each section begins with a table that lists the parameters described in that section, and provides, for each parameter, a reference to the equation(s) and/or section number in the *EPACMTP Technical Background Document* (U.S. EPA, 2003a) that describes how each parameter is used in the EPACMTP computer code.

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2.0 WASTE MANAGEMENT UNIT (SOURCE) PARAMETERS

EPACMTP can simulate the subsurface migration of leachate from four different types of waste management units (WMUs). Each of the four unit types reflects waste management practices that are likely to occur at industrial Subtitle D facilities. The WMU can be a landfill, a waste pile, a surface impoundment, or a land application unit. The latter is also sometimes called a land treatment unit. Figure 2.1 presents schematic diagrams of the different types of WMUs modeled in EPACMTP.

Landfill. Landfills (LFs) are facilities for the final disposal of solid waste on land. EPACMTP is typically used to model closed LFs with an earthen cover. LFs may be unlined, or they may have some type of engineered liner, but the model assumes no leachate collection system exists underneath the liner. The LF is filled with waste during the unit's operational life. Upon closure of the LF, the waste is left in place, and a final soil cover is installed. The starting point for the EPACMTP simulation is the time at which the LF is closed, i.e., the unit is at maximum capacity. The release of waste constituents into the soil and ground water underneath the LF is caused by dissolution and leaching of the constituents due to precipitation which percolates through the LF. The type of liner that is present (if any) controls, to a large extent, the amount of leachate that is released over time from the unit. LFs are modeled in EPACMTP as WMUs with a rectangular footprint and a uniform depth. The EPACMTP model does not explicitly account for any loss processes occurring during the unit's active life (for example, due to leaching, volatilization, runoff or erosion, or biochemical degradation), however these processes will be taken into account if the input value for leachate concentration is based on a site-specific chemical analysis of the waste (such as results from a Toxicity Characteristic Leaching Procedure (TCLP) or Synthetic Precipitation Leaching Procedure (SPLP) analysis). The leachate concentration used as a model input is the expected initial leachate concentration when the waste is 'fresh'. Because the LF is closed, the concentration of the waste constituents will diminish with time due to depletion of the landfilled wastes; the model is equipped to simulate this "depleting source" scenario for LFs, but other source options are available, and are explained in Section 2.3.

Surface Impoundment. A surface impoundment (SI) is a WMU which is designed to hold liquid waste or wastes containing free liquid. SIs may be either ground level or below ground level flow-through units. They may be unlined, or they may have some type of engineered liner. Release of leachate is driven by the ponding of water in the impoundment, which creates a hydraulic head gradient across the barrier underneath the unit. The EPACMTP model considers a SI to be a temporary WMU with a finite operational life. At the end of the unit's operational life, we assume there is no further release of waste constituents to the ground water (that is, there is a clean closure of the SI). SIs are modeled as pulse-type sources; leaching occurs at a constant leachate concentration over a fixed period of time equal to the unit's operating life. The EPACMTP model assumes a constant ponding depth (depth of waste water in SI) during the operational life (see Section 2.2.4).

Waste Pile. Waste piles (WPs) are typically used as temporary storage or treatment units for solid wastes. Due to their temporary nature, they are typically not covered. Similar to LFs, WPs may be unlined, or they may have some type of engineered liner. EPACMTP assumes that WPs have a fixed operational life, after which the WP is removed. Thus, WPs are modeled as pulse-type sources; leaching occurs at a constant leachate concentration over a fixed period of time which is equal to the unit's operating life (see Section 2.5.2).

Land Application Unit. Land application units (LAUs) (or land treatment units) are areas of land receiving regular applications of waste that is either tilled directly into the soil or sprayed onto the soil and then tilled. EPACMTP models the leaching of wastes after they have been tilled with soil. EPACMTP does not account for the losses due to volatilization during or after waste application. LAUs are only evaluated for the no-liner scenario because liners are not typically used at this type of facility. EPACMTP assumes that an LAU is a temporary WMU with a fixed operational life, after which the waste is no longer land-applied. Thus, LAUs are modeled in EPACMTP as a constant pulse-type leachate source, with a leaching duration equal to the unit's operational life (see Section 2.6.2).

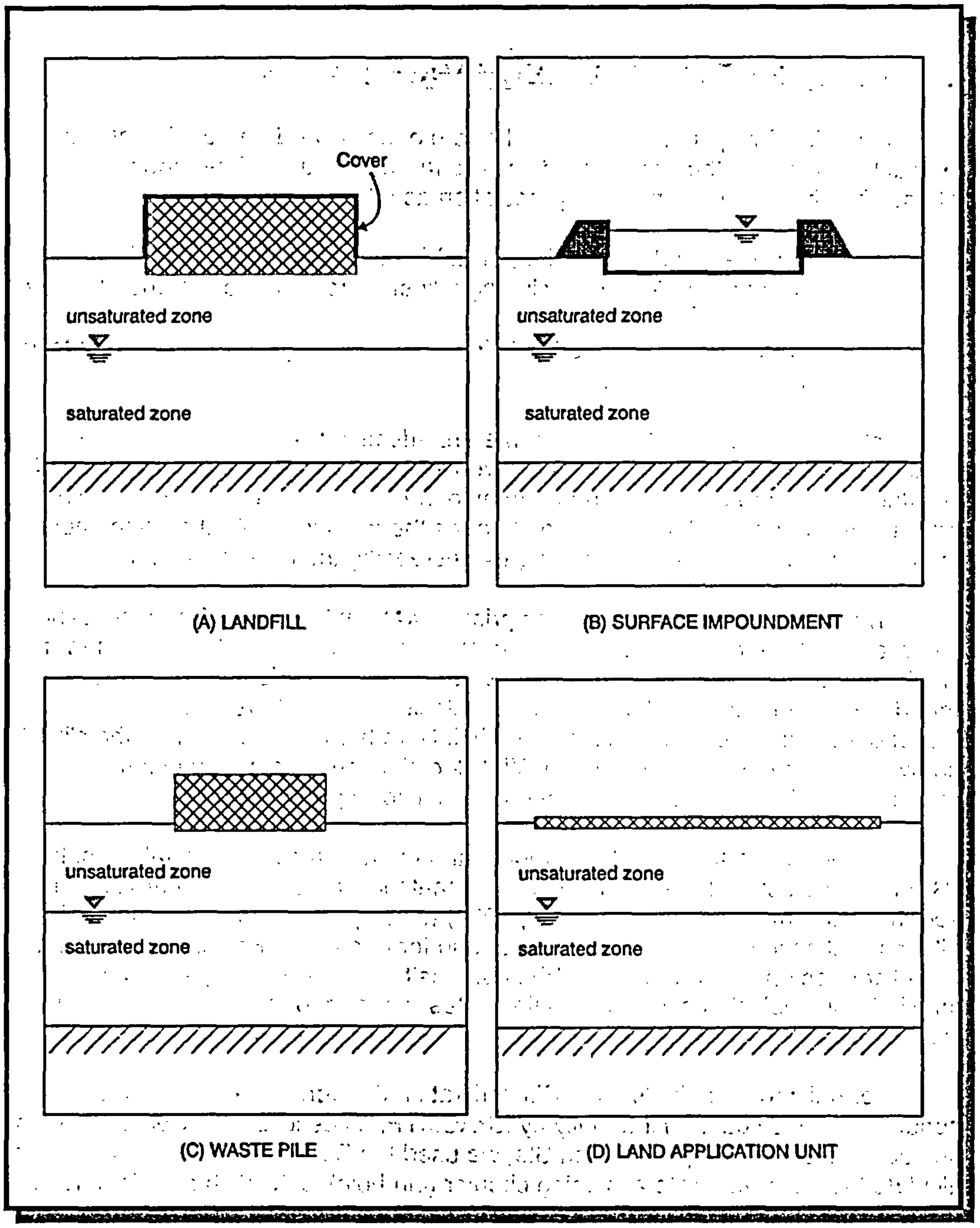

Figure 2.1 WMU Types Modeled in EPACMTP.

APPENDIX A
DETERMINATION OF INFILTRATION AND RECHARGE RATES

A.1 INFILTRATION AND RECHARGE RATES

EPACMTP requires the input of the rate of downward percolation of water and leachate through the unsaturated zone to the water table. The model distinguishes between two types of percolation as infiltration and recharge:

- **Infiltration** (WMU leakage rate) is defined as water percolating through the WMU – including a liner if present – to the underlying soil.
- **Recharge** is water percolating through the soil to the aquifer outside the WMU.

Infiltration is one of the key parameters affecting the leaching of waste constituents into the subsurface. For a given leachate concentration, the mass of constituents leached is directly proportional to the infiltration rate. In EPACMTP, using a different default liner scenario changes the modeled infiltration rate; more protective liner designs reduce leaching by decreasing the rate of infiltration.

In contrast, recharge introduces pristine water into the aquifer. Increasing recharge therefore tends to result in a greater degree of plume dilution and lower constituent concentrations. High recharge rates may also affect the extent of ground-water mounding and ground-water velocity. The recharge rate is independent of the type and design of the WMU; rather it is a function of the climatic and hydrogeological conditions at the WMU location, such as precipitation, evapotranspiration, surface run-off, and regional soil type.

In developing the EPACMTP model and the accompanying databases, the U.S. EPA used several methodologies to estimate infiltration and recharge. We used the HELP model (Schroeder et al, 1994) to compute recharge rates for all units, as well as infiltration rates for LAUs, and for LFs and WPs with no-liner and single-liner designs. For LFs and WPs, composite liner infiltration rates were compiled from leak-detection-system flow rates reported for actual composite-lined waste units (TetraTech, 2001).

For unlined and single-lined SIs, infiltration through the bottom of the impoundment is calculated internally by EPACMTP, as described in Section 4.3.4 of this document. For composite-lined SIs, we used the Bonaparte (1989) equation to calculate the infiltration rate assuming circular (pin-hole) leaks with a uniform leak size of 6 mm^2, and using the distribution of leak densities (number of leaks per hectare) assembled from the survey of composite-lined units (TetraTech, 2001).

Tables A.1 through A.4 summarize the liner assumptions and infiltration rate calculations for LFs, WPs, SIs, and LAUs. The remainder of this appendix provides background on how we used the HELP model in conjunction with data from climate stations across the United States to develop nationwide recharge and infiltration rate distributions and provides a detailed discussion of how we developed infiltration rates for different default liner designs for each type of WMU.

A.1.1 USING THE HELP MODEL TO DEVELOP RECHARGE AND INFILTRATION RATES

The HELP model is a quasi-two-dimensional hydrologic model for computing water balances of LFs, cover systems, and other solid waste management facilities. The primary purpose of the model is to assist in the comparison of design alternatives. The HELP model uses weather, soil and design data to compute a water balance for LF systems accounting for the effects of surface storage, snowmelt, runoff, infiltration, evapotranspiration, vegetative growth, soil moisture storage, lateral subsurface drainage, leachate recirculation, unsaturated vertical drainage, and leakage through soil, geomembrane or composite liners. The HELP model can simulate LF systems consisting of various combinations of vegetation, cover soils, waste cells, lateral drain layers, low permeability barrier soils, and synthetic geomembrane liners.

HELP Versions 3.03 and 3.07 (which include WMU- and liner-specific distributions of infiltration rates) were used to construct the EPACMTP site data files. We started with an existing database of no-liner infiltration rates for LFs, WPs and LAUs. Also existing were recharge rates for 97 climate stations in the lower 48 contiguous United States (ABB, 1995), that are representative of 25 specific climatic regions (developed with HELP version 3.03). We then added five climate stations (located in Alaska, Hawaii, and Puerto Rico) to ensure coverage throughout all of the United States. Figure A.1 shows the locations of the 102 climate stations.

The current version of HELP (version 3.07) was used for the modeling of the additional climate stations for the no-liner scenario. We compared the results of Version 3.07 against Version 3.03 and found that the differences in calculated infiltration rates were insignificant. We also used this comparison to verify a number of counter-intuitive infiltration rates that were generated with HELP Version 3.03. We had observed that for some climate stations located in areas of the country with low precipitation rates, the net infiltration for unlined LFs did not always correlate with the relative permeability of the LF cover. We found some cases in which a less permeable cover resulted in a higher modeled infiltration rate as compared to a more permeable cover. Examples can be seen in the detailed listing of infiltration data that are presented in Tables A.11 to A.14. For instance, Table A.11 shows that for a number of climate stations, including Albuquerque, Denver, and Las Vegas, the modeled infiltration rate for LFs with a silty clay loam (SCL) cover is higher than the values corresponding to silt loam (SLT) and sandy loam (SNL) soil covers. We determined that in all these cases, the HELP modeling results for unlined LFs were correct and could be explained in terms of other water balance components, including surface run-off and evapotranspiration.

Table A.1 Methodology Used to Compute Infiltration for LFs

	No Liner	Single Liner	Composite Liner
Method	HELP model simulations to compute an empirical distribution of infiltration rates for a 2 ft. thick cover of three native soil cover types using nationwide coverage of climate stations. Soil-type specific infiltration rates for a specific site are assigned by using the infiltration rates for respective soil types at the nearest climate station.	HELP model simulations to compute an empirical distribution of infiltration rates through a single clay liner using nationwide coverage of climate stations. Infiltration rates for a specific site were obtained by using the infiltration rate for the nearest climate station.	Compiled from literature sources (TetraTech, 2001) for composite liners
Final Cover	Monte Carlo selection from distribution of soil cover types. 2 ft thick native soil (1 of 3 soil types: silty clay loam, silt loam, and sandy loam) with a range of mean hydraulic conductivities (4.2×10^{-5} cm/s to 7.2×10^{-4} cm/s).	3 ft thick clay cover with a hydraulic conductivity of 1×10^{-7} cm/sec and a 10 ft thick waste layer. On top of the cover, a 1 ft layer of loam to support vegetation and drainage and a 1 ft percolation layer.	No cover modeled; the composite liner is the limiting factor in determining infiltration
Liner Design	No liner	3 ft thick clay liner with a hydraulic conductivity of 1×10^{-7} cm/sec. No leachate collection system. Assumes constant infiltration rate (assumes no increase in hydraulic conductivity of liner) over modeling period.	60 mil HDPE layer with either an underlying geosynthetic clay liner with maximum hydraulic conductivity of 5×10^{-9} cm/sec, or a 3-foot compacted clay liner with maximum hydraulic conductivity of 1×10^{-7} cm/sec. Assumes same infiltration rate (i.e., no increase in hydraulic conductivity of liner) over modeling period.
EPACMTP Infiltration Rate	Monte Carlo selection from HELP generated location- specific values.	Monte Carlo selection from HELP generated location-specific values.	Monte Carlo selection from distribution of leak detection system flow rates.

Table A.2 Methodology Used to Compute Infiltration for SIs

	No Liner	Single Liner	Composite Liner
Method	EPACMTP SI module for infiltration through consolidated sludge and native soil layers with a unit-specific ponding depth from EPA's SI Study (EPA, 2001).	EPACMTP module for infiltration through a layer of consolidated sludge and a single clay liner with unit-specific ponding depth from EPA's SI study.	Bonaparte equation (1989) for pin-hole leaks using distribution of leak densities for units installed with formal CQA programs
Ponding Depth	Unit-specific based on EPA's SI study.	Unit-specific based on EPA's SI study.	Unit-specific based on EPA's SI study.
Liner Design	None. However, barrier to infiltration is provided by layer of consolidated sludge at the bottom of the impoundment, and a layer of clogged native soil below the consolidated sludge. The sludge thickness is assumed to be constant over the modeling period. The hydraulic conductivity of the consolidated sludge is between 1.3×10^{-7} and 1.8×10^{-7} cm/sec. The hydraulic conductivity of the clogged native material is assumed to be 0.1 of the unaffected native material in the vadose zone.	3 ft thick clay liner with a hydraulic conductivity of 1×10^{-7} cm/sec. No leachate collection system. Assumes no increase in hydraulic conductivity of liner over modeling period. Additional barrier is provided by a layer of consolidated sludge at the bottom of the impoundment, see no-liner column.	60 mil HDPE layer with either an underlying geosynthetic clay liner with maximum hydraulic conductivity of 5×10^{-9} cm/sec, or a 3-foot compacted clay liner with maximum hydraulic conductivity of 1×10^{-7} cm/sec. Assumptions: 1) constant infiltration rate (i.e., no increase in hydraulic conductivity of liner) over modeling period; 2) geomembrane liner is limiting factor that determines infiltration rate.
EPACMTP Infiltration Rate	Calculated by EPACMTP based on Monte Carlo selection of unit-specific ponding depth.	Calculated based on Monte Carlo selection of unit-specific ponding depth	Calculated based on Monte Carlo selection of unit-specific ponding depth and distribution of leak densities

Table A.3 Methodology Used to Compute Infiltration for WPs

	No Liner	Single Liner	Composite Liner
Method	HELP model simulations to compute distribution of infiltration rates for a 10 ft. thick layer of waste, using three waste permeabilities (copper slag, coal bottom ash, coal fly ash) and nationwide coverage of climate stations. Waste-type-specific infiltration rates for a specific site are obtained by using the infiltration rates for respective waste types at the nearest climate station.	HELP model simulations to compute distribution of infiltration rates through 10 ft. waste layer using three waste permeabilities and nationwide coverage of climate stations. Infiltration rates for a specific site were obtained by using the infiltration rate for the nearest climate station.	Compiled from literature sources (TetraTech, 2001) for composite liners
Cover	None	None	None
Liner Design	No liner.	3 ft thick clay liner with a hydraulic conductivity of 1×10^{-7} cm/sec, no leachate collection system, and a 10 ft thick waste layer. Assumes no increase in hydraulic conductivity of liner over unit's operational life.	60 mil HDPE layer with either an underlying geosynthetic clay liner with maximum hydraulic conductivity of 5×10^{-9} cm/sec, or a 3-foot compacted clay liner with maximum hydraulic conductivity of 1×10^{-7} cm/sec. 1) same infiltration rate (i.e., no increase in hydraulic conductivity of liner) over unit's operational life; 2) geomembrane is limiting factor in determining infiltration rate.
EPACMTP Infiltration Rate	Monte Carlo selection from HELP generated location-specific values.	Monte Carlo selection from HELP generated location- specific values.	Monte Carlo selection from distribution of leak detection system flow rates

Table A.4 Methodology Used to Compute Infiltration for LAUs

	No Liner	Single Liner	Composite Liner
Method	HELP model simulations to compute an empirical distribution of infiltration rates for a 0.5 ft thick sludge layer, underlain by a 3 ft layer of three types of native soil using nationwide coverage of climate stations. Soil-type specific infiltration rates for a specific site are assigned by using the infiltration rates for respective soil types at the nearest climate station.	N/A	N/A
Liner Design	No liner	N/A	N/A
EPACMTP Infiltration Rate	*Monte Carlo selection from HELP generated location specific values.*	N/A	N/A